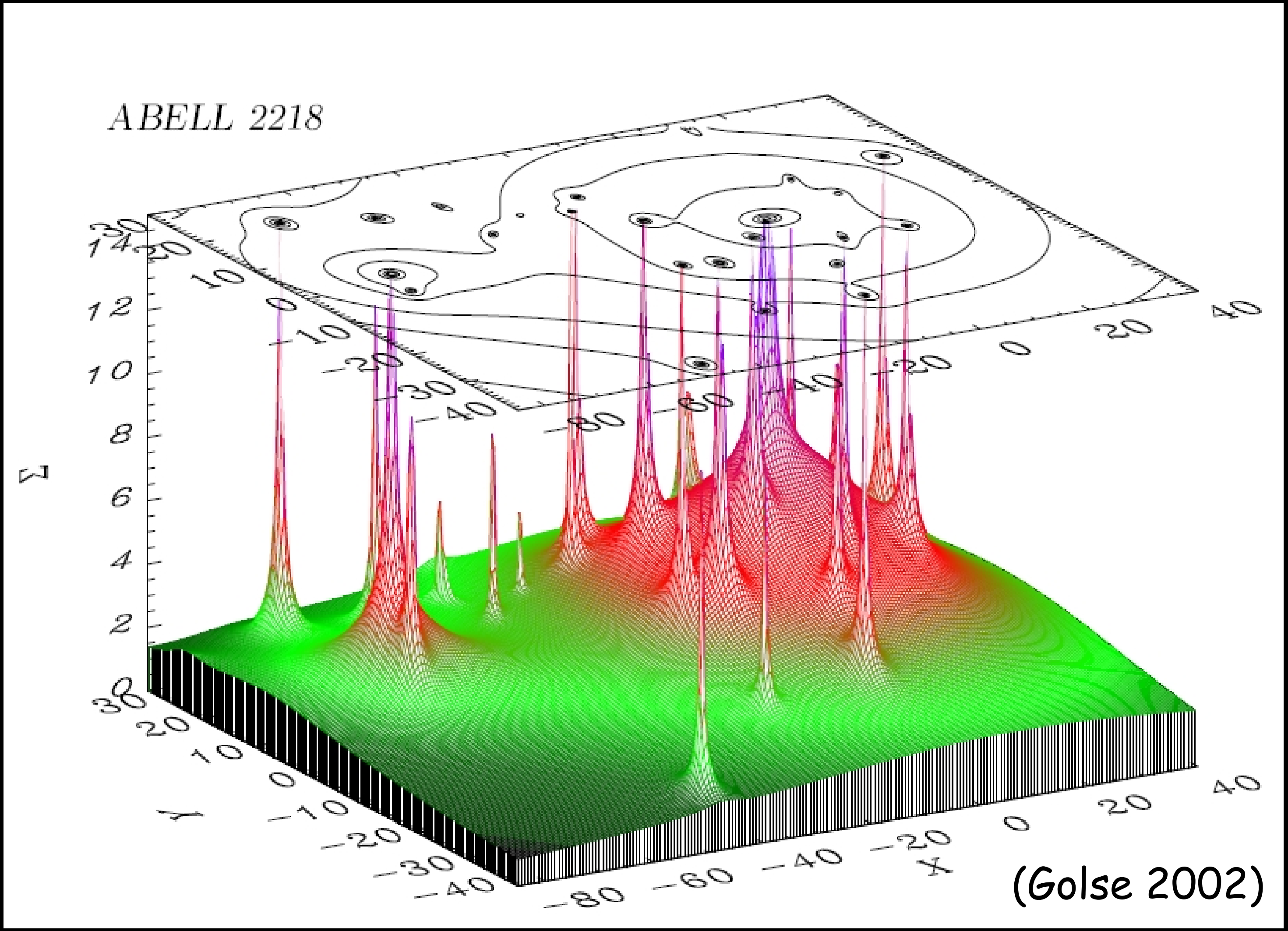
Strong Lensing modelling techniques in Clusters of Galaxies

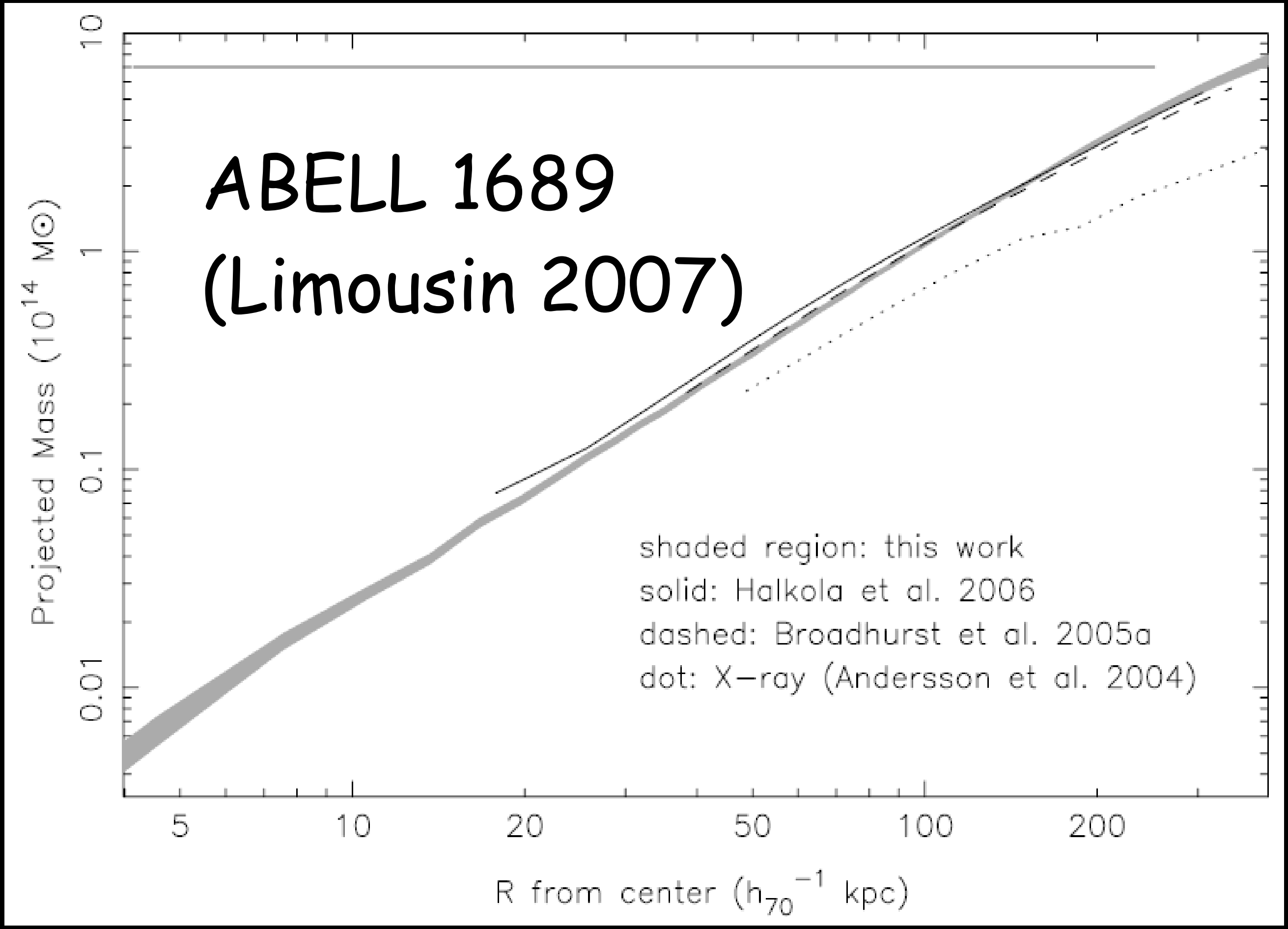
Eric.Jullo @ OAMP.fr – MPE, Garching 2008



(Golse 2002)

PhD Supervisor: Jean-Paul Kneib

Xray - lensing mass discrepancy

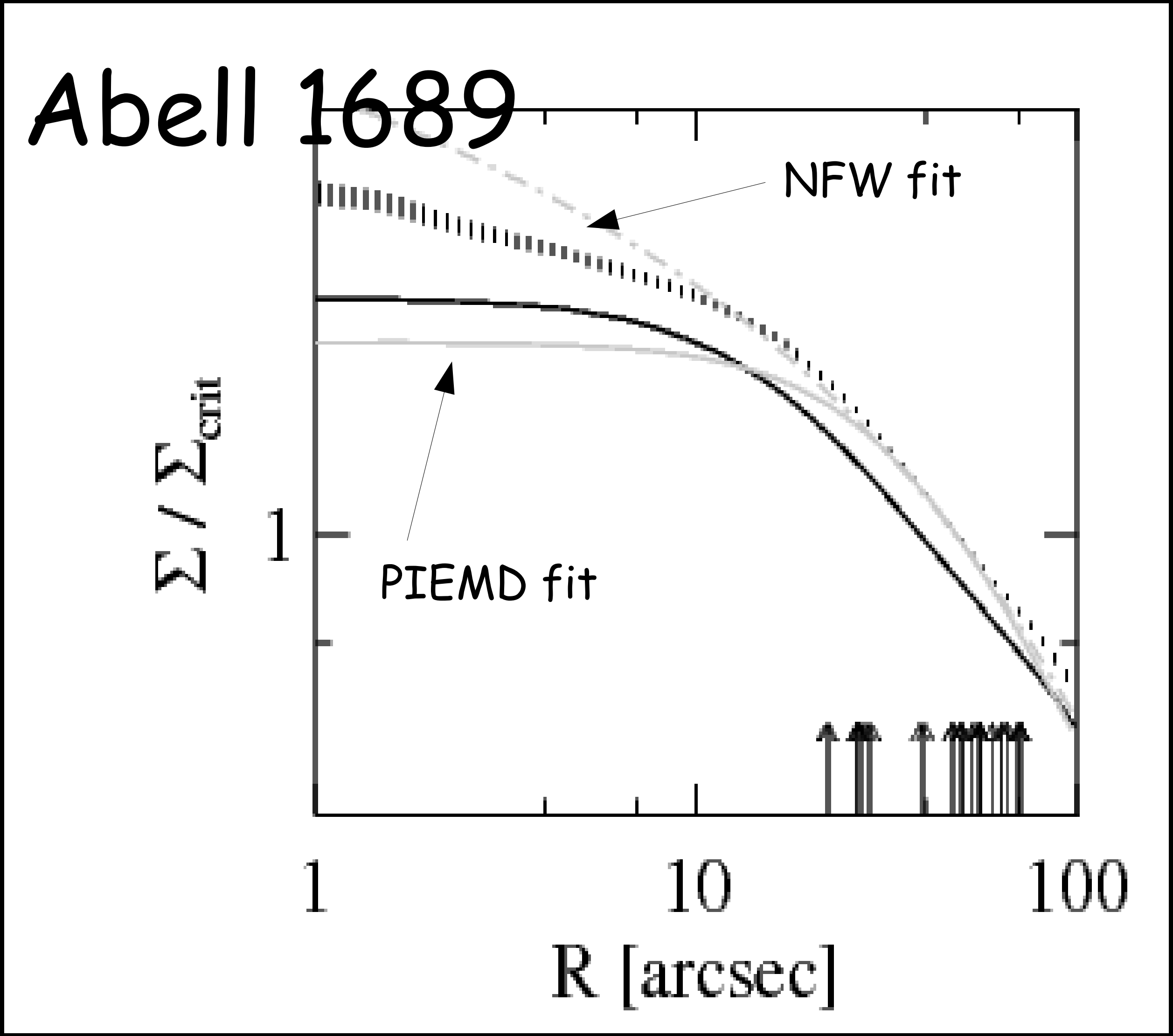


A merger along the line of sight?
(Anderson & Madejski 2004)

Explanation

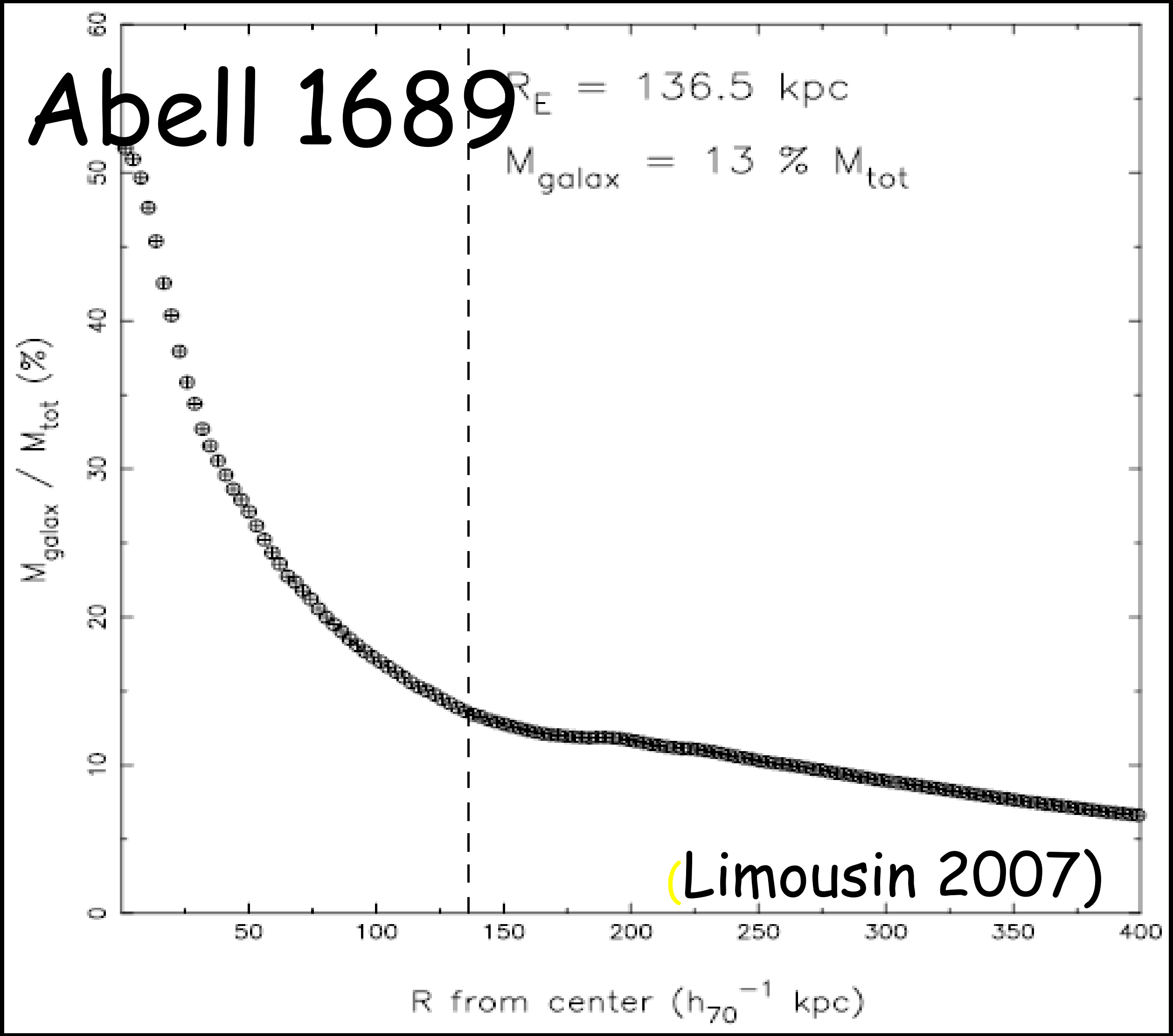
- Bartelmann96:
  - More elliptical + More subst. = more multiple images
  - More subst. in unrelaxed clusters (merging, cf Graham & Taylor2008)
  - Xray mass of unrelaxed clusters is usually underestimated (non thermal emission, non spherical symmetry)

Explanation



OR missing the mass of subst. ?

Explanation



OR missing the mass of subst.?

How to estimate mass of subst.?

- Their degeneracies with cluster scale component(s)

Outlines

- "Non parametric" techniques
- Parametric techniques
- Mixed technique parametric & non parametric
- Can we trust lensing mass maps?
  - Physical parameters systematics
  - Non physical parameters systematics

SL Modeling techniques

- Lensing Parametric models are observationally and physically motivated description of DM halos

- Lensing "Non parametric" models are systematic descriptions of DM halos (grids).

They could lead (in the future) to automatic modelling ("assumption free models")?

SL Modeling techniques

‼ All Models are parametric ‼

- Le… ametric models are observa… nd physically motivated description o… los

- Lensing "Non parametric" m… e… systematic descriptions of DM … ids).

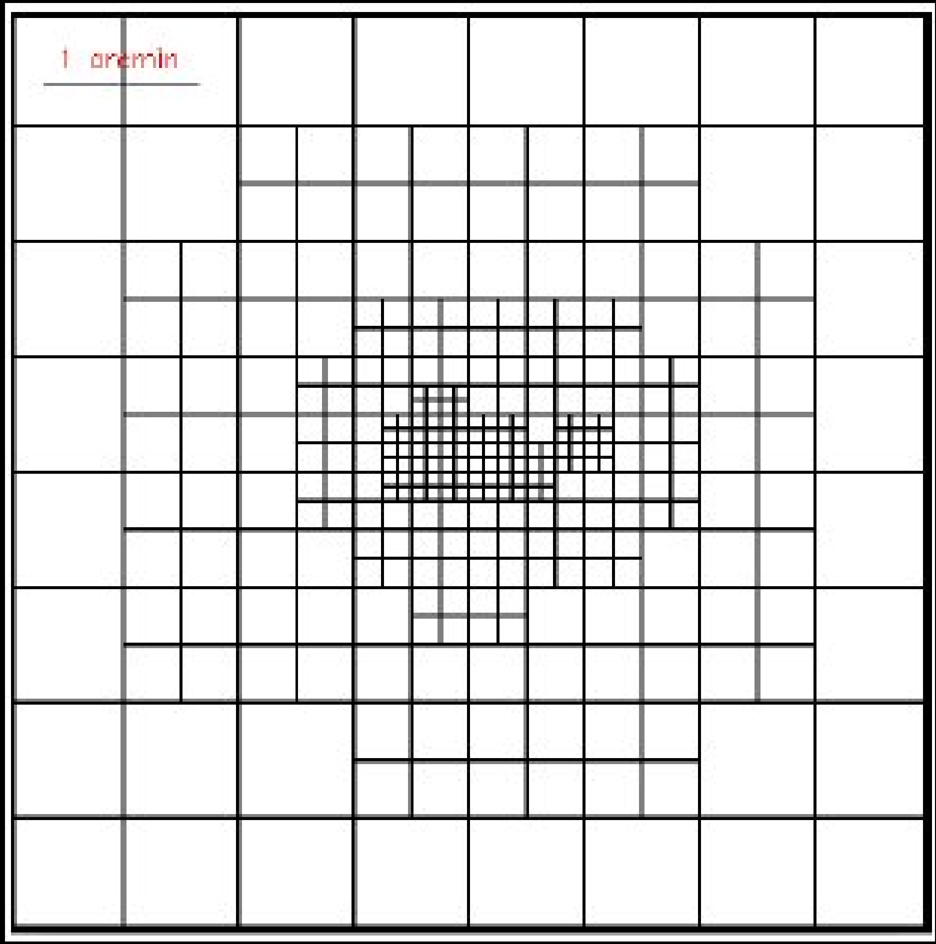
They could lead (in the future) to auton… modelling ("assumption free models")?

"Non parametric" techniques

Usual approach :

- Grid of pixels of mass or potentials (Bradač 2005)
- Compute predictions by interpolating these quantities at the position of the strong or weak lensing constraints
- Minimise $\chi^2 = \left(\frac{prediction - observation}{\sigma_{pos}} \right)^2$

!! N free parameters > N constraints !!



Adaptive gridding (Diego et al. 2005)

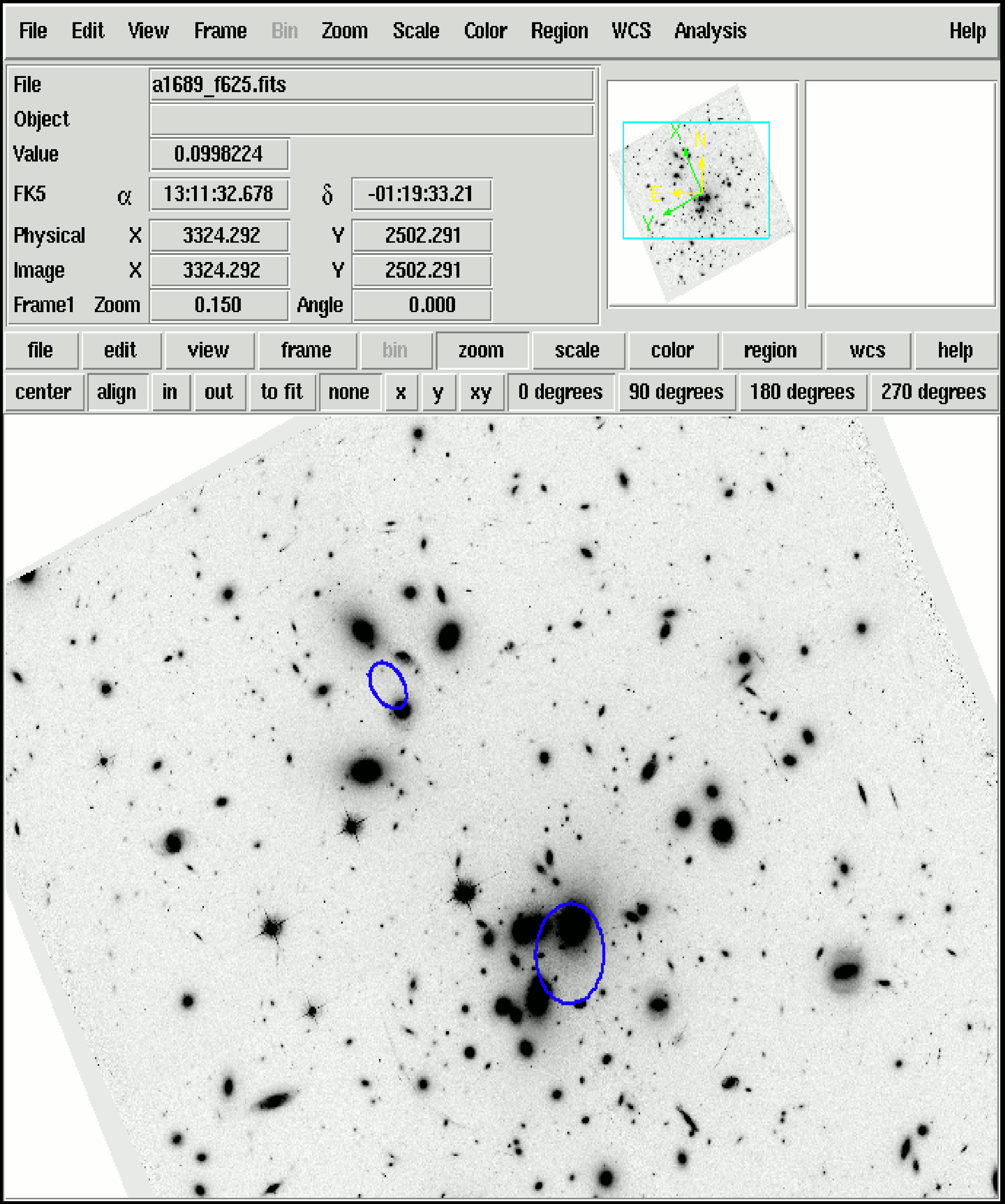
+ Very flexible models
- Many solutions → Regularisation schemes

FEW STUDIES OF SYSTEMATICS EFFECTS **(Abelsalam98 rotated grid technique)**

Parametric techniques

Lenstool code

1) Place the potentials on the cluster

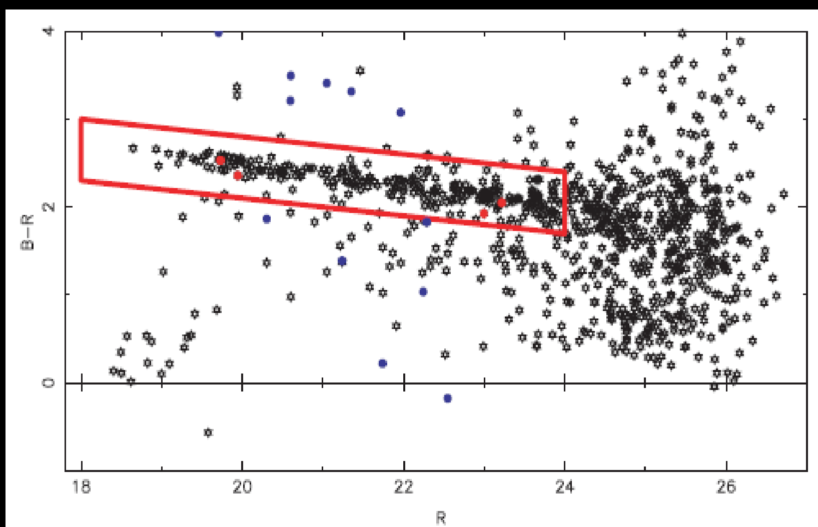


Parametric techniques

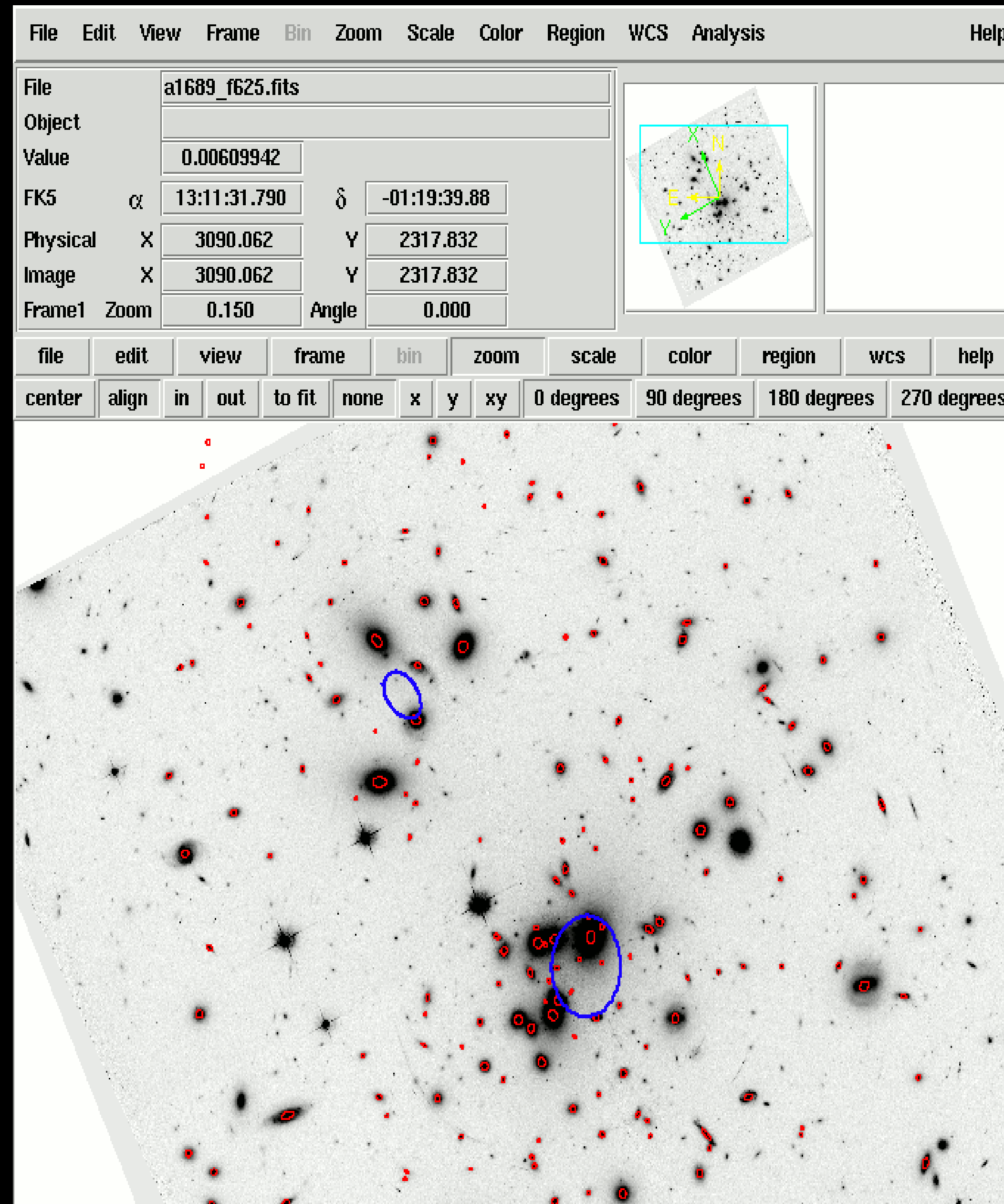
Lenstool code

1)Place the potentials on the cluster

2)Add galaxy members



Color magnitude diagram
(Limousin et al 2007)



Reduce Nb of free parameters: Scaling relations

- Galaxy scale halos are described by PIEMD potentials and scaling relations

$$r_{core} = r^{\star}_{core}\left(\frac{L}{L^{\star}}\right)^{1/2} \qquad r_{cut} = r^{\star}_{cut}\left(\frac{L}{L^{\star}}\right)^{1/2} \qquad \sigma_0 = \sigma^{\star}_0\left(\frac{L}{L^{\star}}\right)^{1/4}$$

- $r^{\star}_{core}$ is fixed
- $r^{\star}_{cut}$ and $\sigma^{\star}_0$ are the 2 only remaining free parameters for the galaxy scale clumps

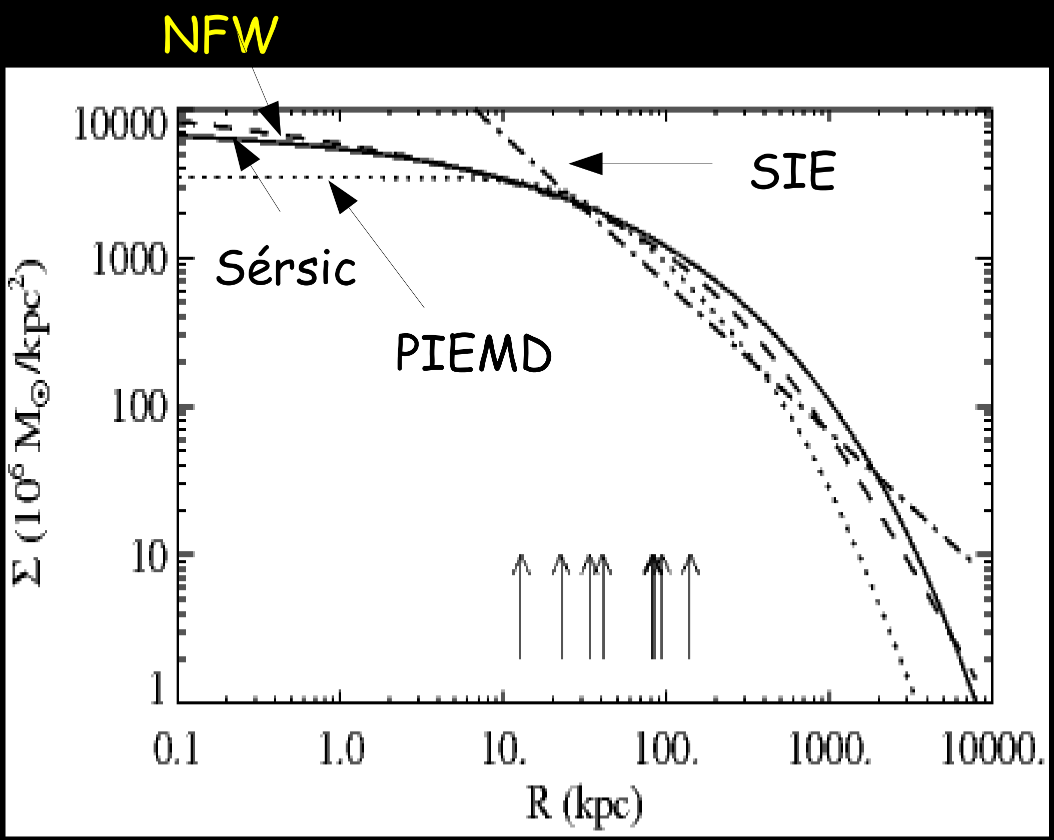
Parametric techniques

Lenstool code

1)Place the cluster scale mass clumps

2)Add galaxy members

3)Assign a potentials to the clumps



(Jullo et al 2007)

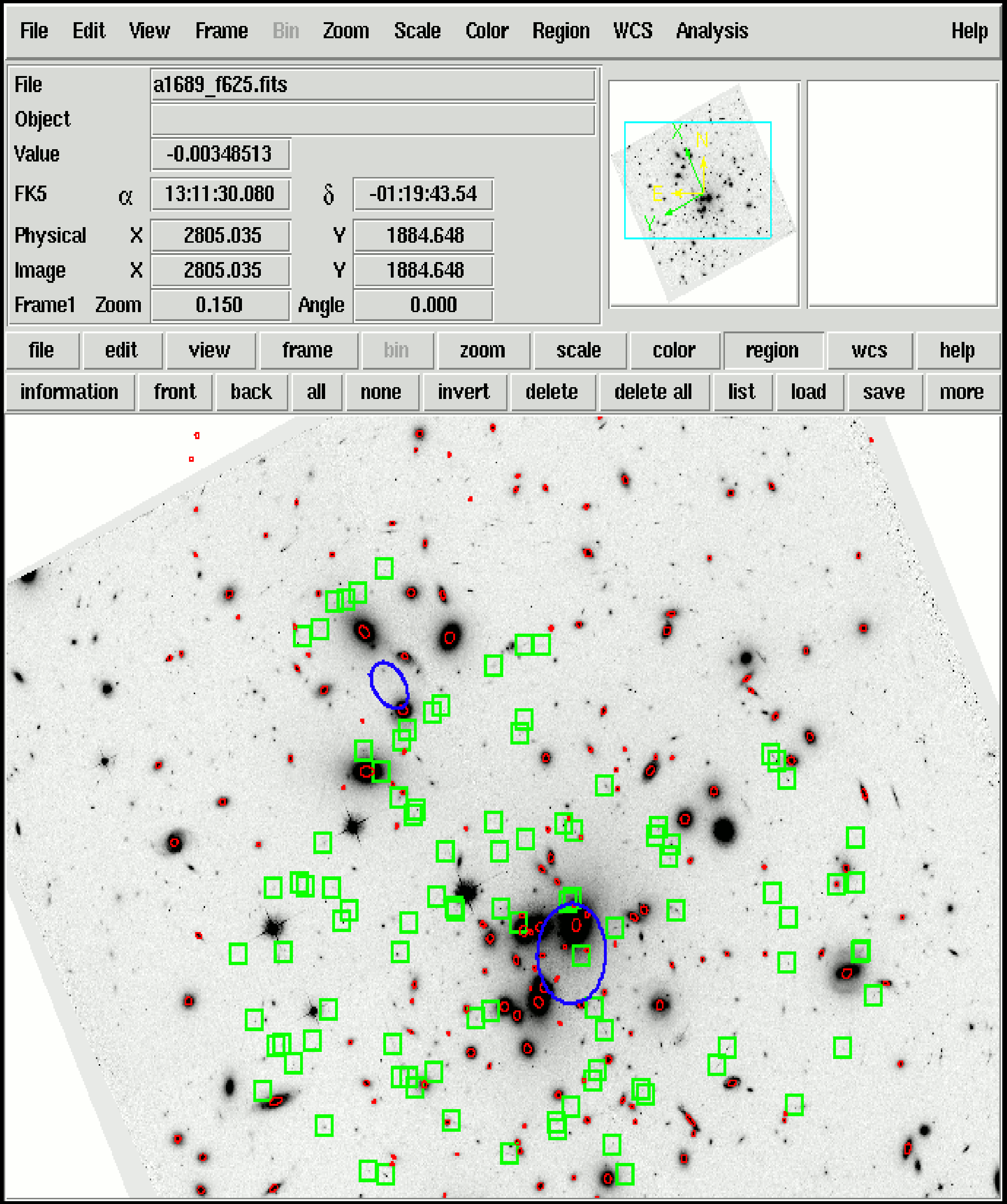
PIEMD surface density :

$$\Sigma(R) = \frac{\sigma_0^2}{2G} \frac{r_{cut}^2}{r_{cut}^2 - r_{core}^2} \left(\frac{1}{\sqrt{r_{core}^2 + R^2}} - \frac{1}{\sqrt{r_{cut}^2 + R^2}} \right)$$

Parametric techniques

Lenstool code

1) Place the cluster scale mass clumps
2) Add galaxy members
3) Assign a potentials to the clumps
4) Add the constraints



Parametric techniques

Lenstool code

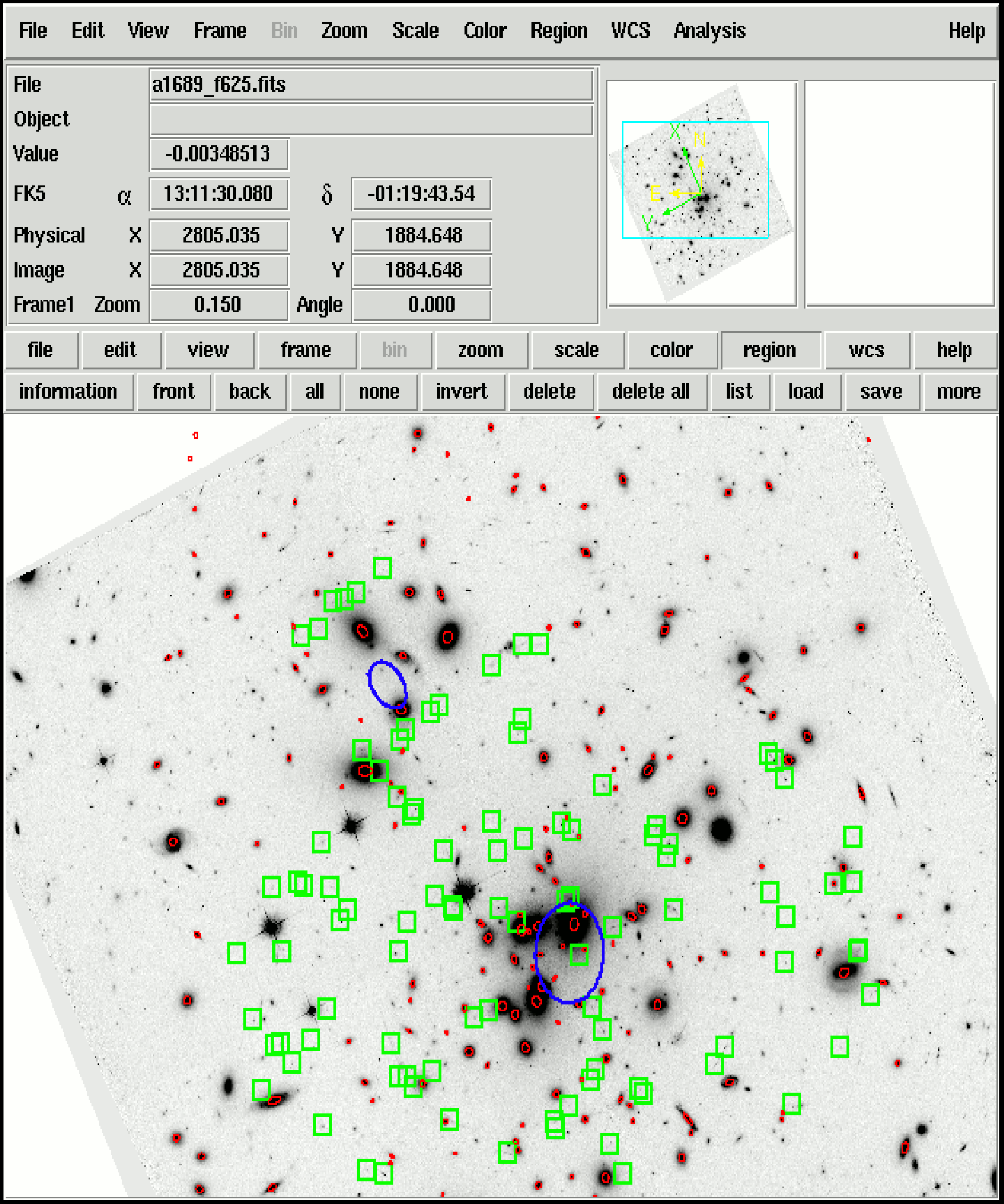
1) Place the cluster scale mass clumps

2) Add galaxy members

3) Assign a potentials to the clumps

4) Add the constraints

5) X^2 → best fit model



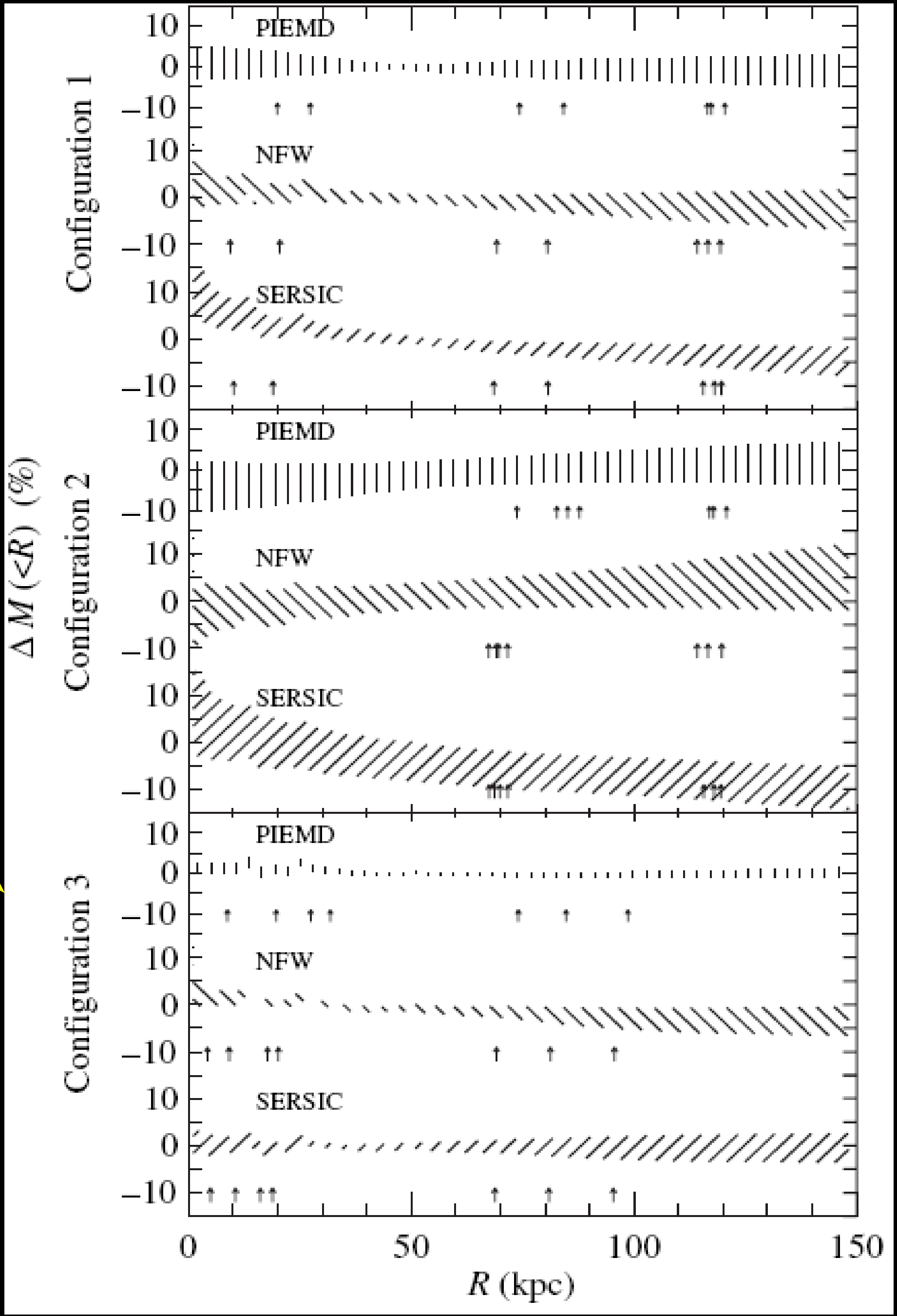
Dependance on the SL config.

Mass constraints

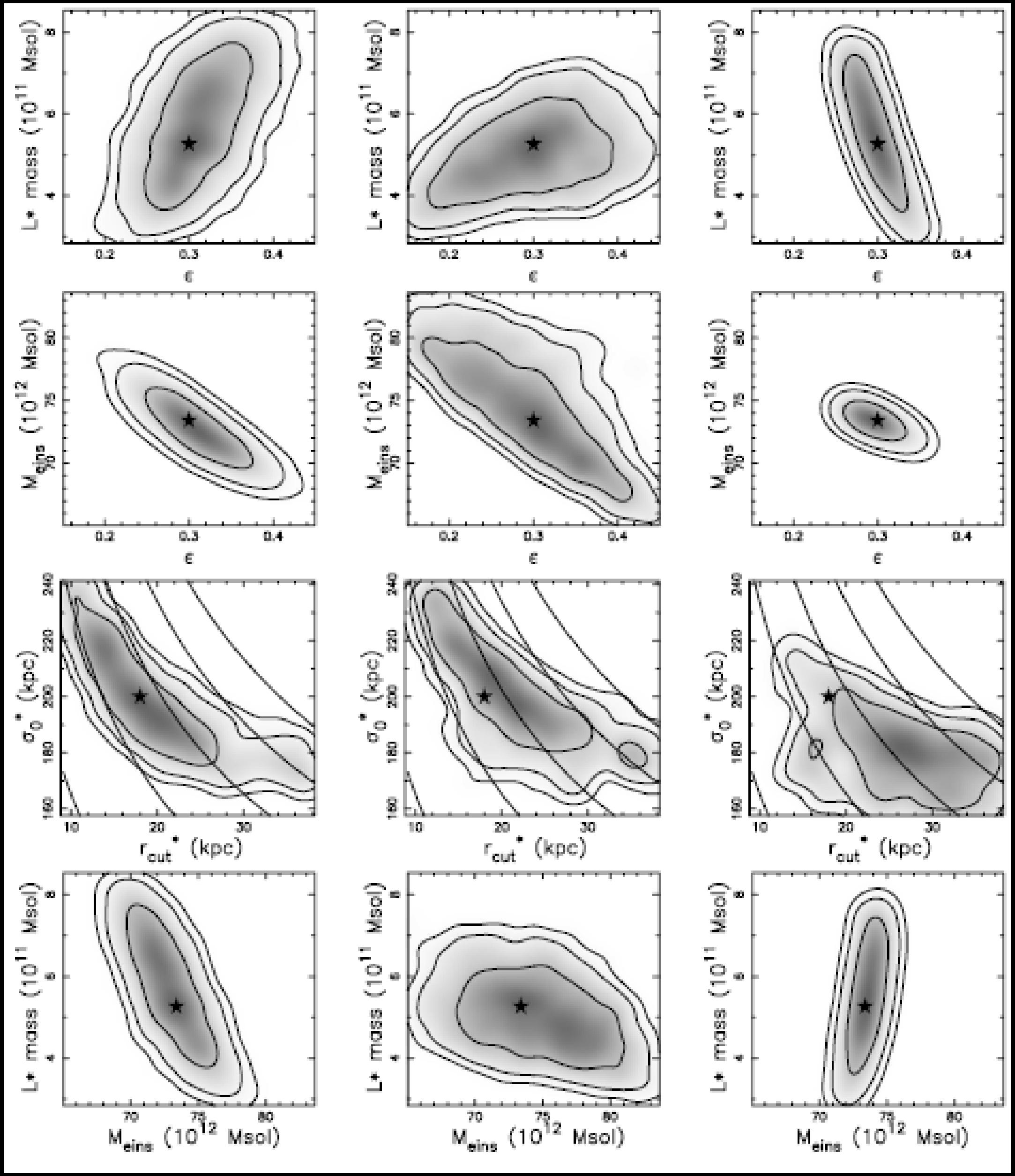
3 different SL lensing simulations with 7 images from 3 sources at redshifts $z_s = 0.6 \rightarrow 4$

$z_{lens} = 0.2$

(Jullo et al. 2007)



Degeneracies between parameters



Ext+int | Ext only | Mainly Int

Mass degeneracies

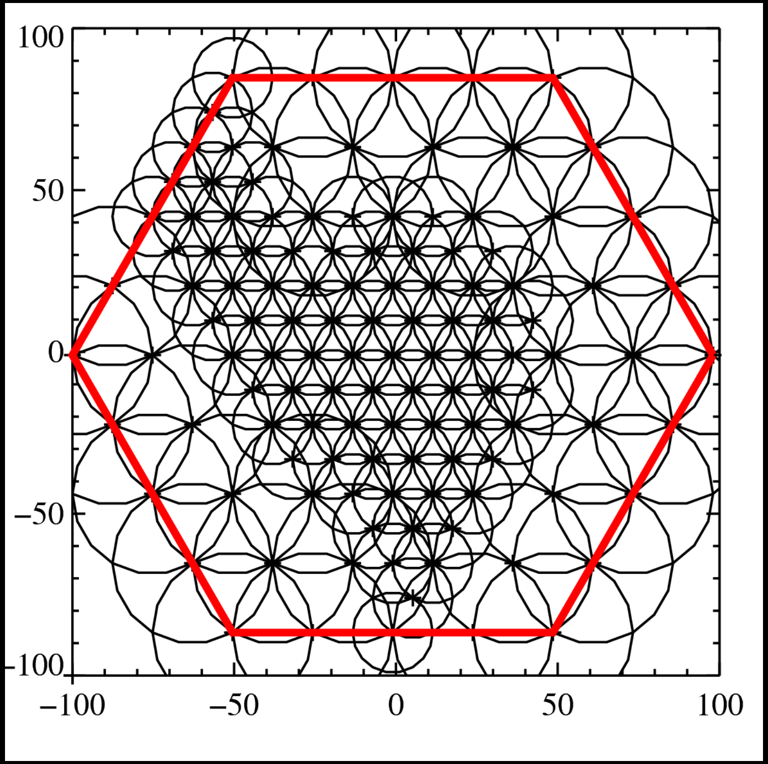
Bayesian MCMC sampler of the posterior Pr(θ|D)*

*Lenstool code

Adaptative grid model

(Jullo & Kneib, submitted)

➔ Multiscale-grid of 120 PIEMD clumps with free σ_0 but fixed r_{core} ,r_{cut} and position



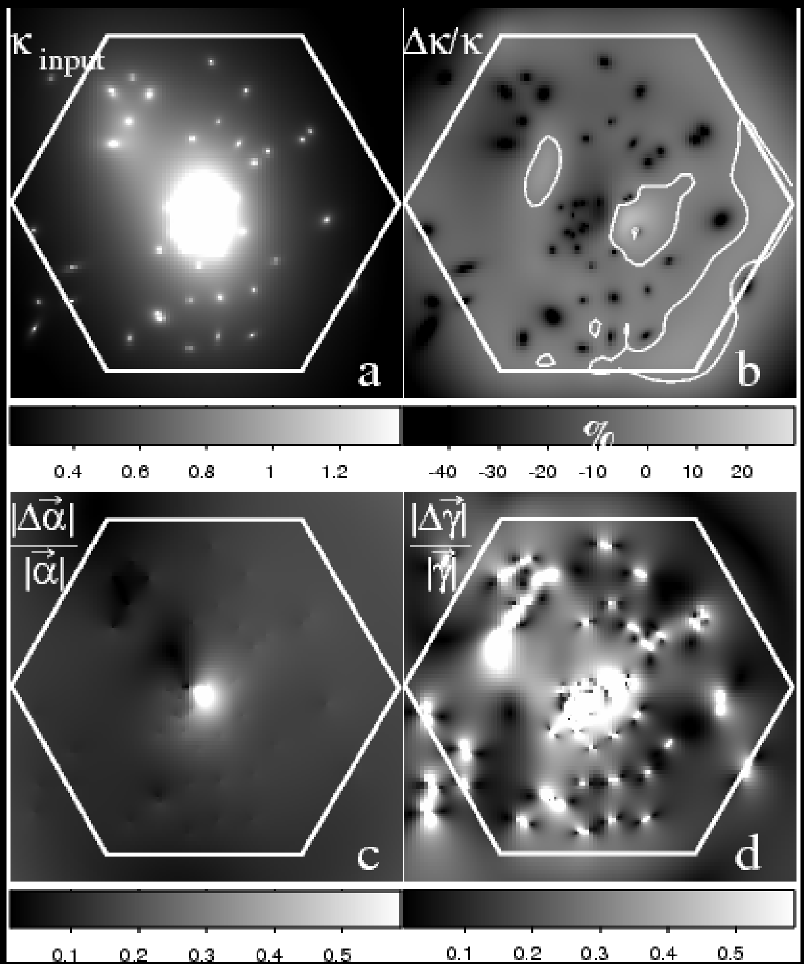
ACS field of A1689

Hexagonal limits and cristal-packed grid of nodes to match the natural shape of clusters

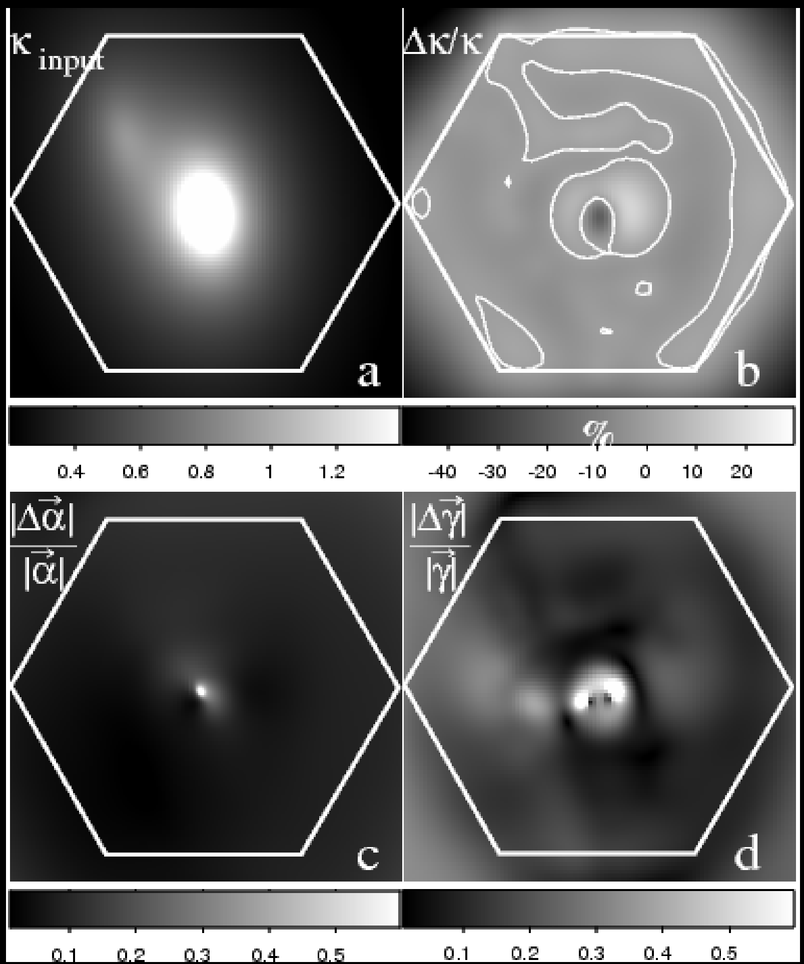
Splitting of triangles according to a mass density threshold

PIEMD r_{cut}/r_{core} = 3 is a good ratio

Adaptative grid model

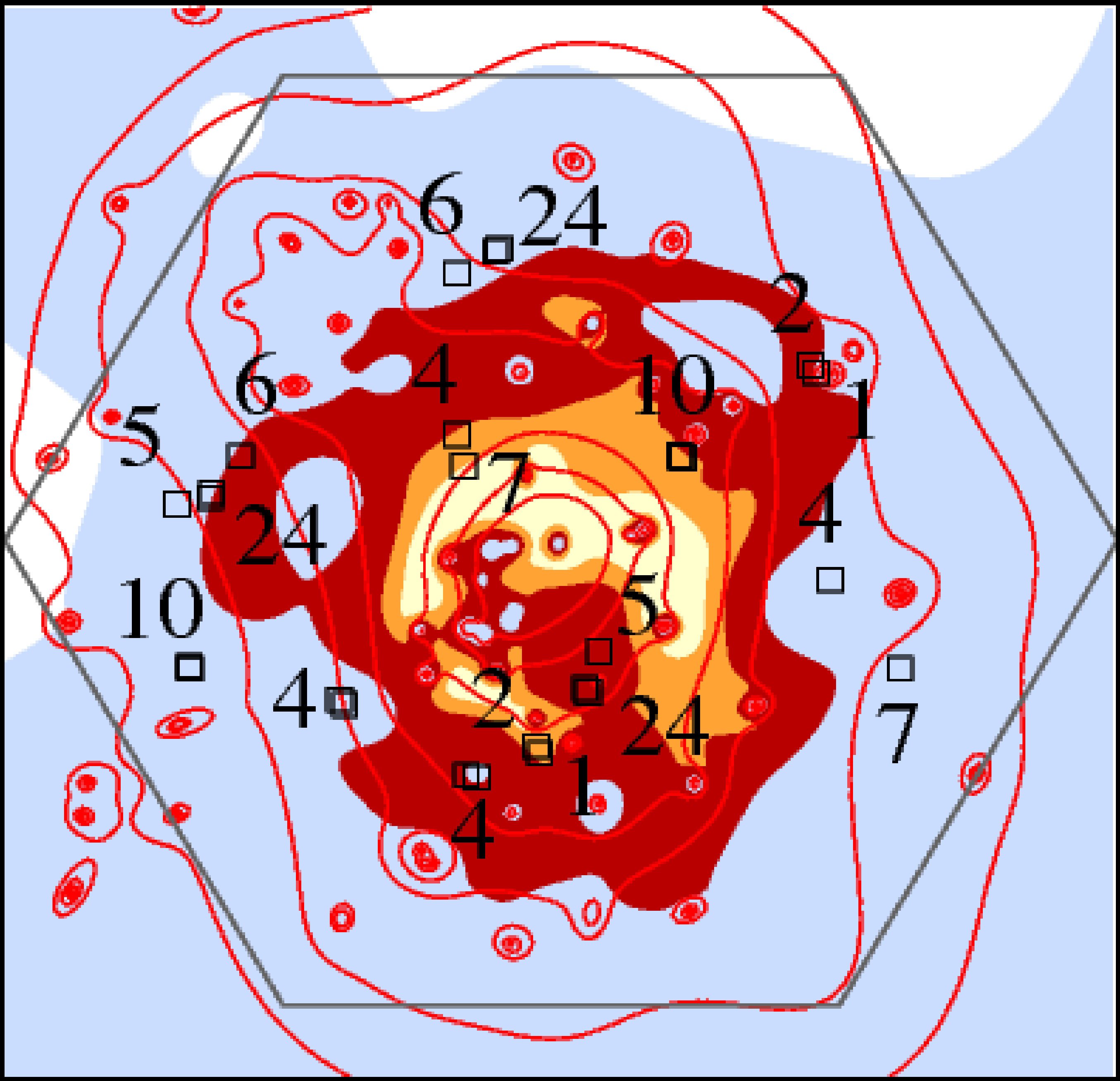


Adaptive grid alone – Input model



(Adaptive grid + galaxy scale halos) – Input Model

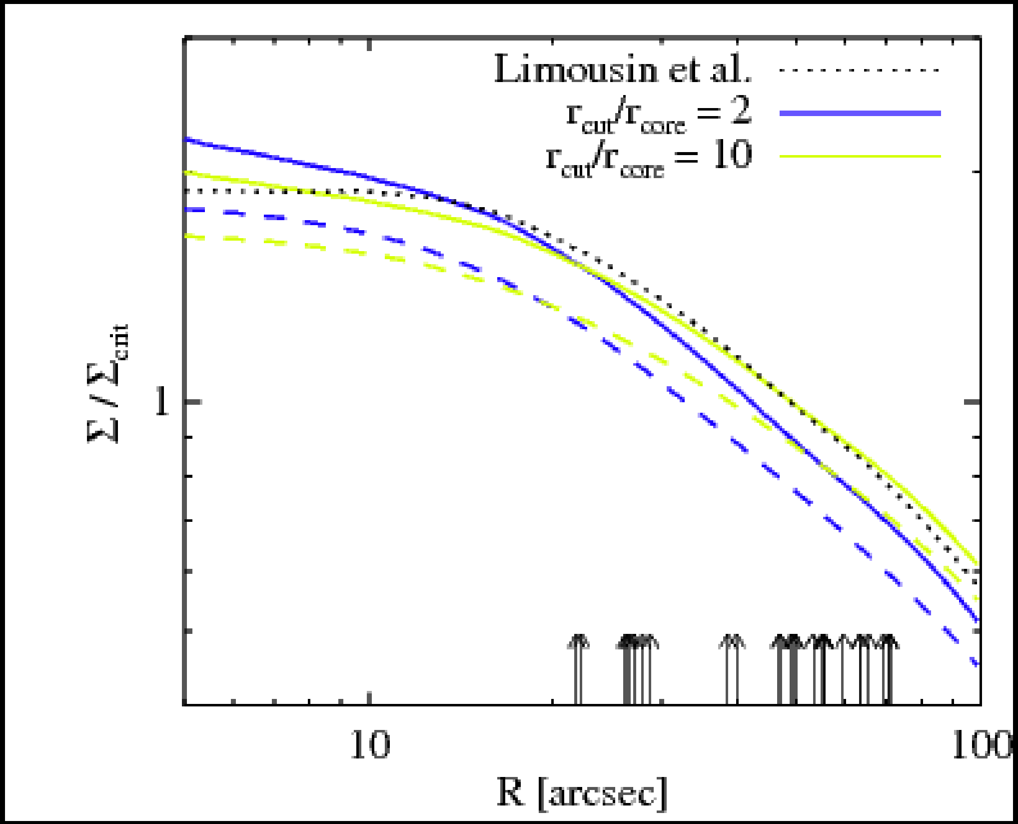
Mass map + Error estimation



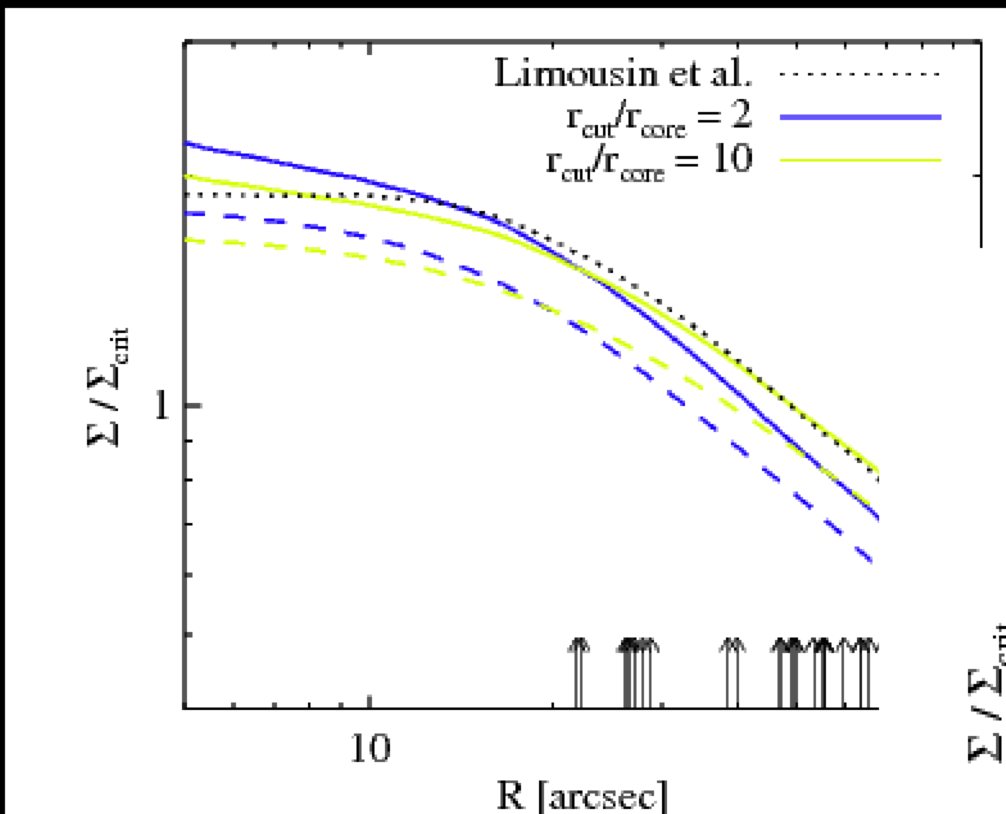
With 3 levels of splitting
rcut/rcore=3

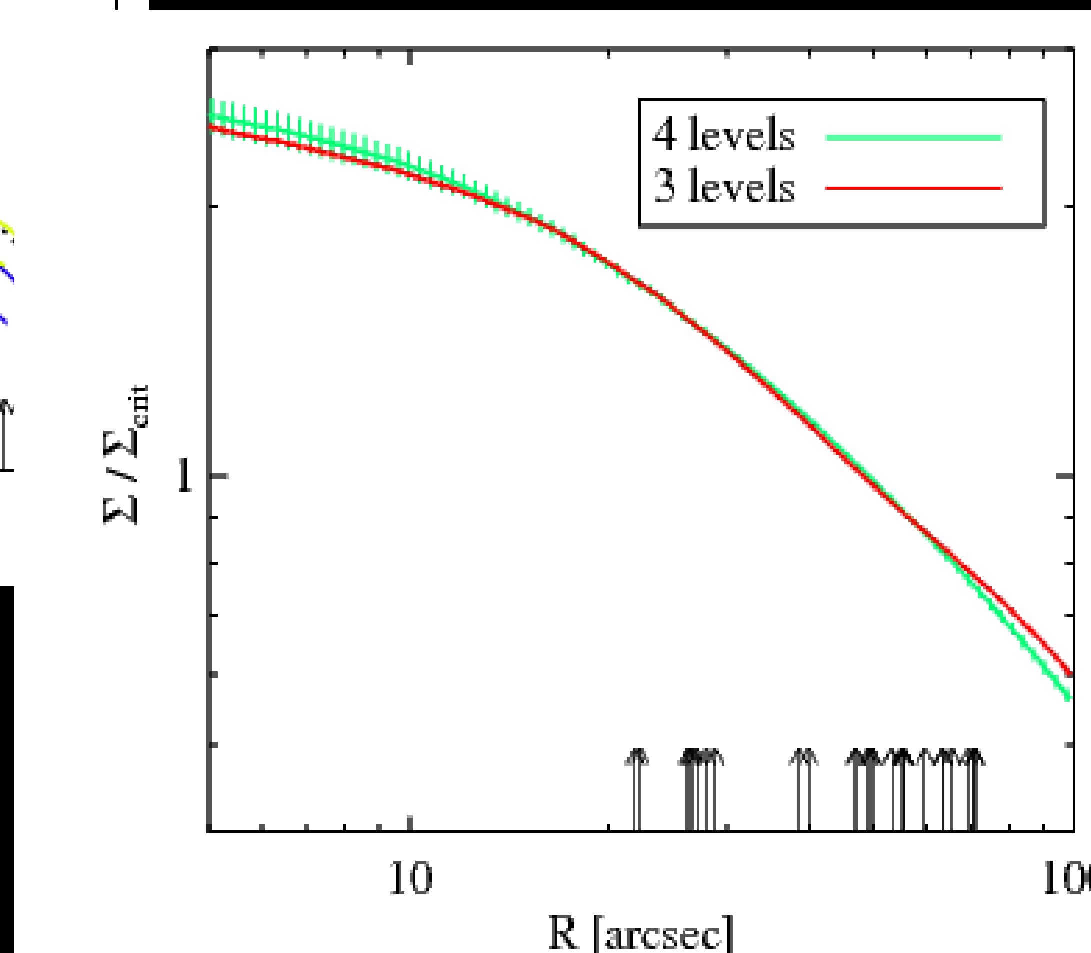
12 systems of multiple images

Systematics due to non parametric parameters

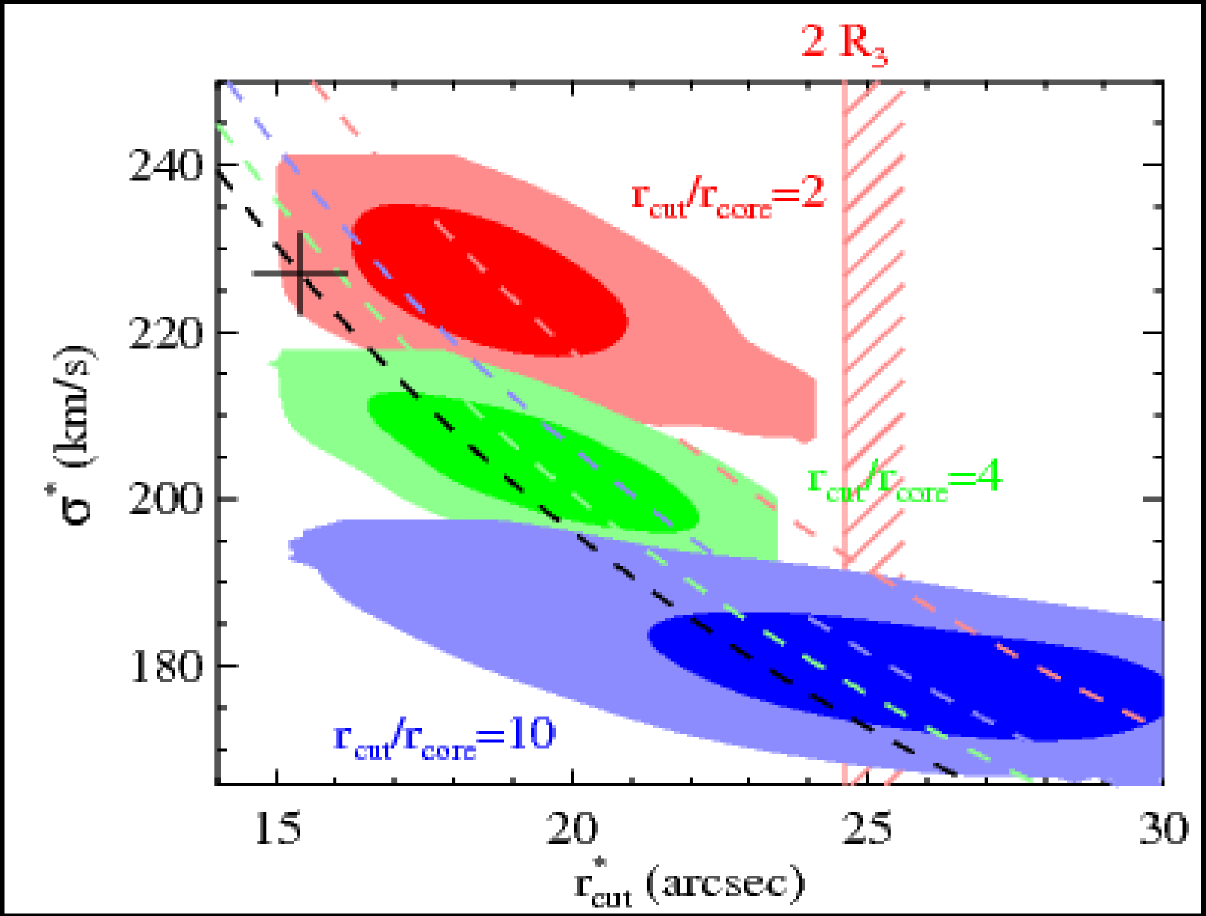


Systematics due to non parametric parameters





Degeneracies between grid & subst.



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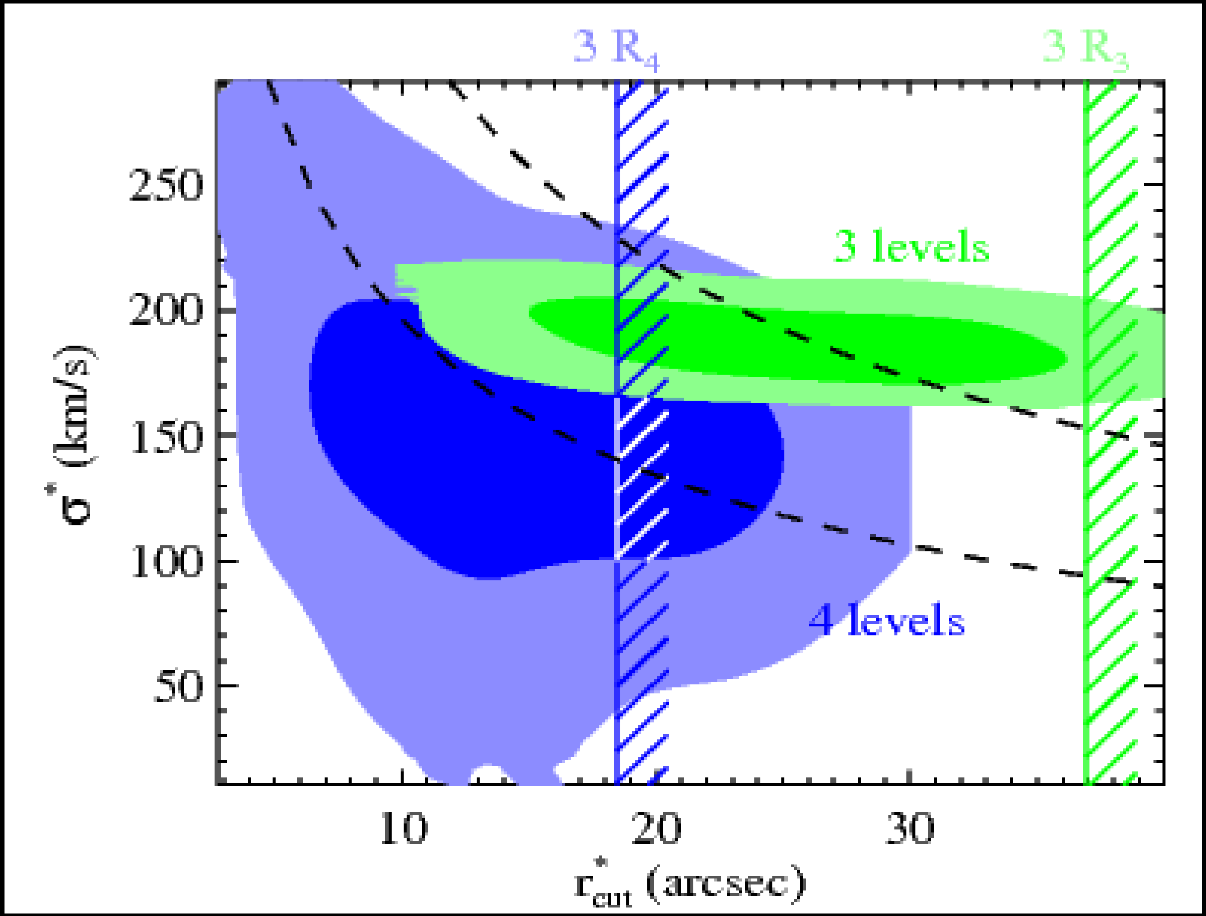
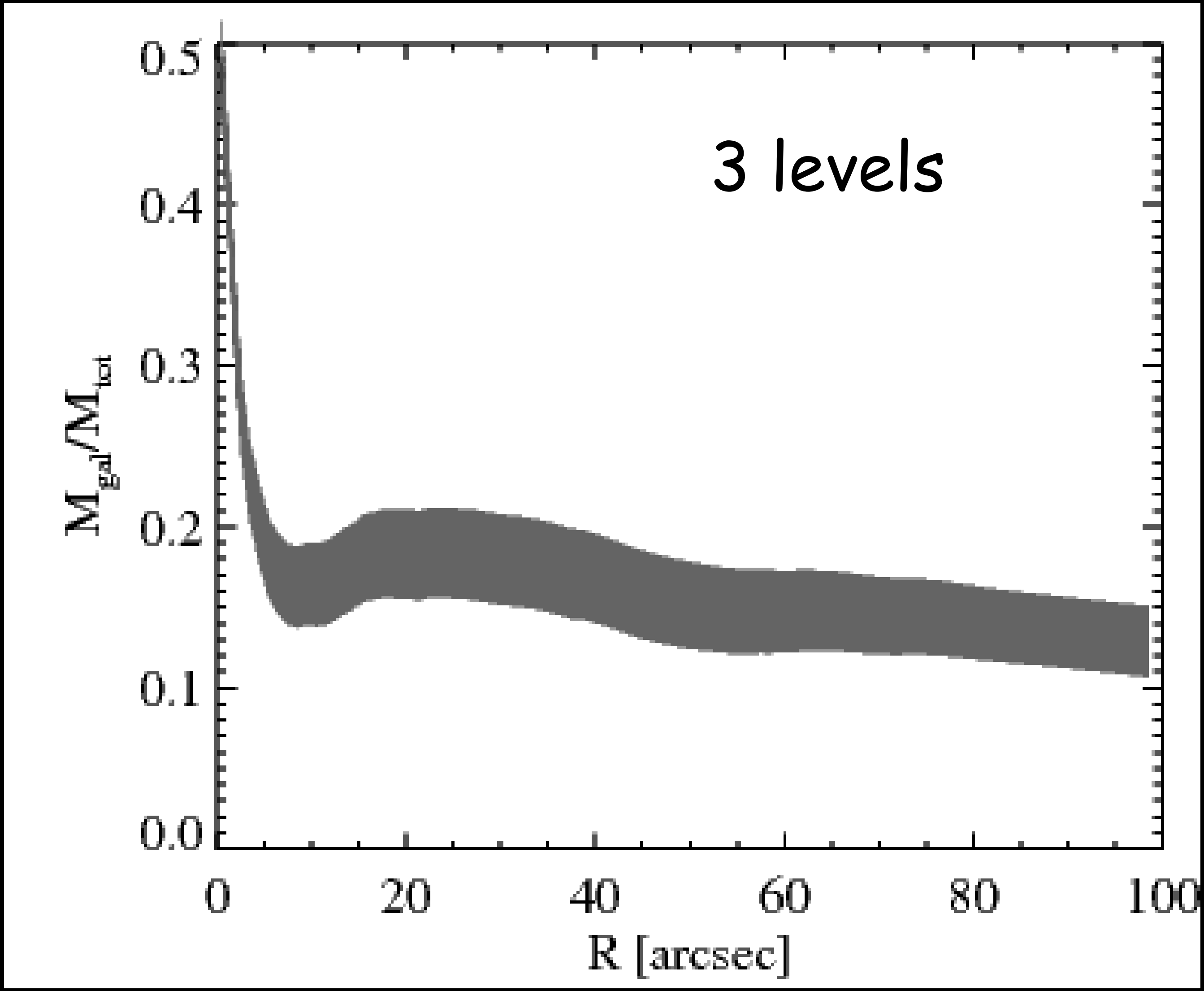
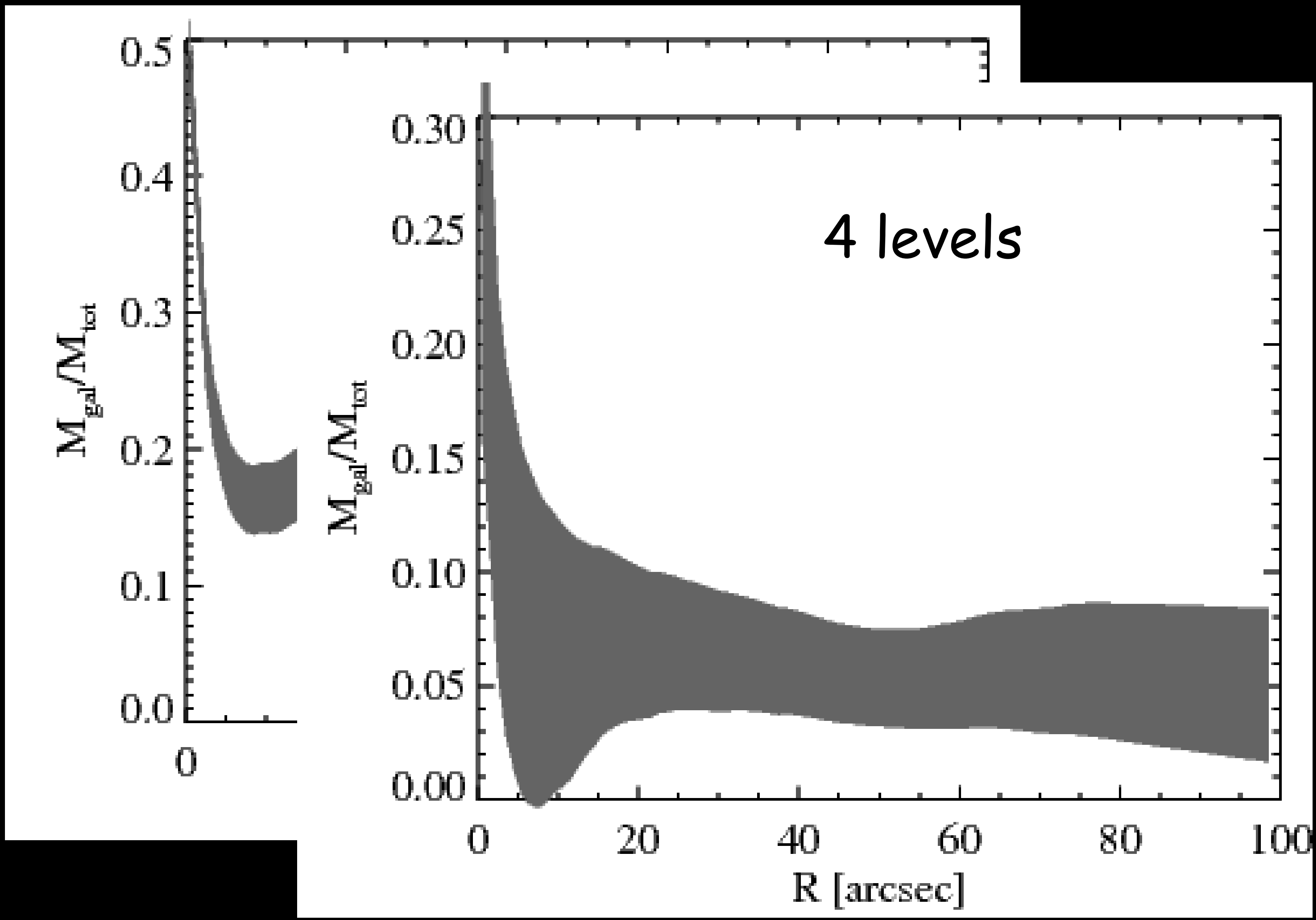


➔Hard to estimate with confidence the mass of subst.

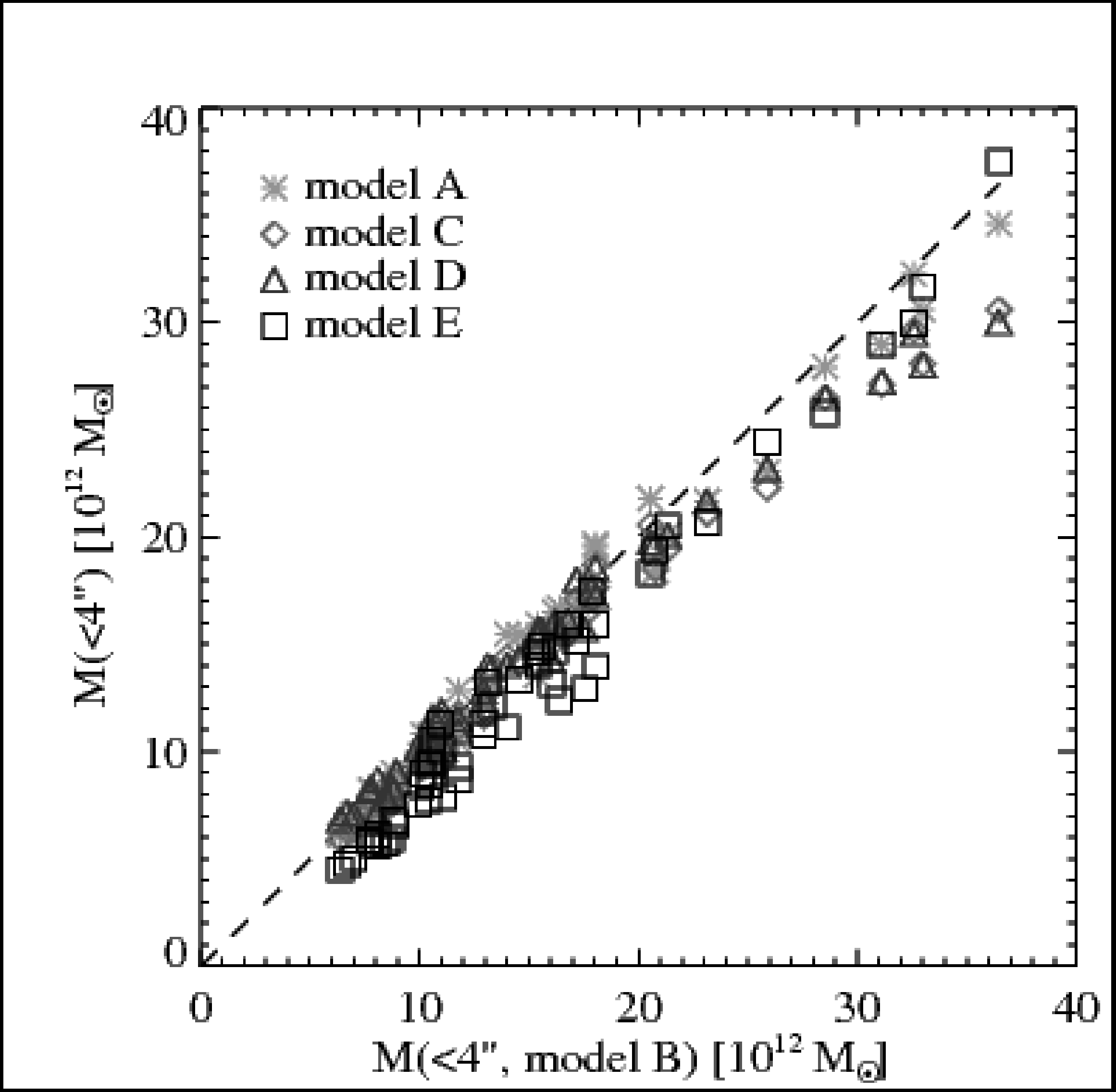
Overall with grid models



Overall with grid models



Invariant quantity



Aperture mass around observed galaxies

Future applications of grid modelling

- Straightforward combination WL + SL thanks to :
  - adaptive grid
  - Analytic potentials → forward fitting technique in which we do not linearize lensing equation (WL)
- Try to map the mass in the COSMOS field
- Study the application of grid models to estimate cosmological parameters